

**ST. LAWRENCE RIVER
ENVIRONMENTAL INVESTIGATIONS**

VOLUME 2

**ENVIRONMENTAL QUALITY ASSESSMENT
OF THE
ST. LAWRENCE RIVER IN 1985
AS REFLECTED BY THE
DISTRIBUTION OF
BENTHIC INVERTIBRATE COMMUNITIES**

FEBRUARY 1988



**Environment
Ontario**

Jim Bradley
Minister

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VOLUME 2

ENVIRONMENTAL QUALITY ASSESSMENT
OF THE ST. LAWRENCE RIVER IN 1985 AS REFLECTED BY
THE DISTRIBUTION OF BENTHIC INVERTEBRATE COMMUNITIES

Report Prepared for:
Ontario Ministry of the Environment
Water Resources Branch
Great Lakes Section

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FOREWORD

This study was designed and supervised by Y. Hamdy of the Great Lakes Section, Water Resources Branch. This report has been reviewed by staff of the Water Resources Branch and Southeastern Region, Ontario Ministry of the Environment.

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TABLE OF CONTENTS

LIST OF TABLES	ii
LIST OF FIGURES	iii
ACKNOWLEDGEMENTS	iv
SUMMARY	v
INTRODUCTION	1
METHODS	
Study Rationale	2
Sampling Design	3
Data Analysis	5
RESULTS AND DISCUSSION	
Benthic Communities	9
Environmental Quality Evaluation	15
St. Lawrence Environmental Quality Zones	25
Temporal Changes in the Environmental Quality	30
LITERATURE CITED	31
APPENDIX	
1: A List of the Major Taxonomic References.	
2: Species Composition (No. per 516 cm ²) of Sampling Stations in the St. Lawrence River near Cornwall, July 1985.	
3: Field Observations of the St. Lawrence River Survey, July 1985.	

LIST OF TABLES

Table	Title	Page
1	Species composition (mean number per 516 cm ²) of benthic communities 1-6 in the St. Lawrence River, near Cornwall.	10
2	Species composition (mean number per 516 cm ²) of benthic communities A-F in the St. Lawrence River, near Cornwall.	12
3	Correlations between the physicochemical variables and the first two discriminant functions.	17
4	Mean values of physicochemical sediment variables associated with benthic communities 1-6.	18
5	Mean values of physicochemical sediment variables associated with benthic communities A-F.	24

LIST OF FIGURES

Figure	Title	Page
1	Locations of sampling stations in the St. Lawrence River, near Cornwall.	4
2	Distribution of benthic invertebrate communities in the St. Lawrence River, near Cornwall.	14
3	Plot of benthic invertebrate communities in discriminant space as defined by the first two discriminant functions.	16
4	Abundance of invertebrates by functional-feeding group in benthic communities 1-6.	21
5	Abundance of invertebrates by functional-feeding group in benthic communities A-F.	23
6	Environmental Quality interpretation of benthic invertebrate communities.	26
7	Distribution of Environmental Quality Zones in the St. Lawrence River, near Cornwall.	27

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I would like to thank Bill Girard at the Cornwall Sewage Treatment Plant for providing us with space to process the benthic samples, and historical information about the area. I would also like to express my gratitude to the staff of the Great Lakes Section of the Water Resources Branch for their valuable comments on earlier drafts of this report.

SUMMARY

In July of 1985, the Ontario Ministry of the Environment conducted a benthic invertebrate and sediment chemistry survey of the St. Lawrence River near Cornwall, Ontario and Massena, New York to determine the effect of point source discharges on the environmental quality of the river.

In the north channel of the river, a zone of impaired environmental quality resulting from sediment accumulations of coarse particulate organic matter (wood fibre and chips) extended downriver from Domtar Fine Papers to Pilon Island. Zones of poor environmental quality occurred downriver of the diffusers of Courtaulds along the north shore, and downriver of the Cornwall sewage treatment plant discharge along the south shore of Pilon Island and along the north shore of the river from Farlinger's to Flanigan's Point. In addition, a localized zone of degraded environmental quality resulting from the saturation of the sediments with oils and grease occurred adjacent to an oil storage depot along the Cornwall waterfront.

A large zone of slightly impaired environmental quality extended from Pilon Island to the end of Ile Sainte-Regis. This area received a significant flow of water from the south channel of the river which diluted the wastes from the north channel and thus reduced the environmental impact. This zone may represent the area of the river that has recovered from historic industrial waste loadings.

Eutrophic conditions were evident throughout the remainder of the river, with the exception of less eutrophic conditions at the confluences of the Grasse, Raquette and St. Regis Rivers with the St. Lawrence River. No point source effects on benthic communities were noted in the south channel.

Notwithstanding the conditions noted along the Cornwall waterfront, a considerable improvement in the environmental quality was evident over the past 19 years.

RÉSUMÉ

En juillet 1985, le ministère de l'Environnement de l'Ontario a réalisé une analyse chimique des sédiments et des invertébrés benthiques du Saint-Laurent, près de Cornwall (Ontario) et de Massena (New York), afin d'évaluer les effets des polluants provenant de sources ponctuelles sur la qualité environnementale du fleuve.

On a observé, dans une partie du chenal nord du fleuve, une dégradation résultant de la sédimentation de matières organiques grossières (fibres et copeaux de bois) s'étendant en aval de la société Domtar Fine Papers jusqu'à l'île Pilon. Une détérioration de l'eau a également été constatée en aval des diffuseurs de Courtaulds le long de la rive nord, et en aval de l'usine d'épuration des eaux usées de Cornwall, le long du littoral sud de l'île Pilon et le long de la rive nord du fleuve depuis Farlinger's Point jusqu'à Flannigan's Point. On a enfin observé, dans une zone réduite adjacente à un entrepôt de pétrole, sur la rive de Cornwall, une dégradation de la qualité de l'environnement causée par la saturation des sédiments en huiles et en graisses.

Une grande zone dont la qualité est légèrement détériorée s'étend depuis l'île Pilon jusqu'à la pointe de l'île Saint-Regis. Cette zone reçoit un débit d'eau important provenant du chenal sud du fleuve, ce qui dilue les eaux usées du chenal nord et en réduit ainsi les effets. Cette zone est peut-être représentative de la section du fleuve qui s'est remise de la pollution industrielle subie par le passé.

Le reste du fleuve se trouve dans un état d'eutrophisation marqué, sauf aux confluents des rivières Grasse, Raquette et St. Regis, où l'eutrophisation serait moins avancée. Les déversements ponctuels ne semblent avoir eu aucun effet sur le benthos du chenal sud.

Exception faite du rivage de Cornwall, on constate une amélioration considérable de la qualité de l'environnement depuis dix-neuf ans.

INTRODUCTION

The St. Lawrence River near Cornwall, Ontario and Massena, New York has been designated as an "Area of Concern" by the IJC (IJC 1982). Studies by the Ontario Ministry of the Environment in 1979 revealed that the levels of PCBs, cadmium, chromium, copper, iron, lead, mercury, zinc, total phosphorus, total Kjeldahl nitrogen, and oils and grease in the sediments along the Cornwall waterfront, and at the mouth of the Grasse River near Massena exceeded the Ministry's guidelines for open water disposal of dredged sediments (OMOE 1986). Levels of PCBs, cadmium, copper, iron and zinc were also above their respective guidelines in sediments collected close to the outfalls of Reynolds Metals Co. and General Motors Foundary to the St. Lawrence River. Industrial and municipal discharges along the Ontario shoreline from Domtar Fine Papers, Canadian Industries Ltd., Courtaulds, BCL of Canada Ltd., and the Cornwall sewage treatment plant and along the New York shoreline from Reynolds Metals Co. and General Motors Foundary have contributed to the impairment and restriction of water use in the area (OMOE 1986).

The objectives of this study were to assess the effect of these contaminants on the aquatic biota and to determine the extent of the impact of point source discharges on the environmental quality of the St. Lawrence River. Thus, the Ontario Ministry of the Environment conducted a benthic invertebrate and sediment chemistry survey of the river in July of 1985. Furthermore, this study provides the baseline conditions for future studies that will monitor the change in the quality of the river in response to the implementation of control measures on the municipalities and industries of the area.

METHODS

Study Rationale:

Benthic invertebrates have long been recognized for their value as indicators of environmental quality. They have been found to show a wide range of tolerances to various degrees and types of pollution. They are generally abundant in all aquatic habitats, easily collected and readily identified. Because of their low motility and habitat preference, they usually remain in a localized area where they are continuously subjected to the full rigor of the local environment. Since they must endure all environmental extremes over their life-cycle, which may vary from about six months to two years, they indicate the past as well as the present environmental conditions of a site.

In addition, benthic invertebrates occupy an intermediate trophic level in aquatic food-webs. They feed on periphyton (ie. scrapers), leaf litter and other coarse particulate organic matter (ie. shredders), detritus and other fine particulate organic matter (ie. collectors) and invertebrates (ie. predators), and in turn are an important source of food for animals in higher trophic levels, most notably fish and waterfowl. Thus they may be used to evaluate biotic as well as abiotic environmental disturbances.

Unlike water or surficial sediment samples, which only indicate the total concentration of contaminants in the environment at a point-in-time, benthic invertebrates represent the integration of all environmental variables (biotic and abiotic), including the bio-availability of contaminants over the period of time they have lived in the habitat. The use of in-situ organisms therefore circumvents the need for any assumptions about the toxicity of contaminant concentrations in sediments and eliminates the need for the frequent sampling of water to measure temporally fluctuating contaminant levels in order to assess the effects of contaminants on aquatic life.

Sampling Design:

Benthic macroinvertebrate samples were collected by the Ontario Ministry of the Environment from July 1 to 12, 1985, at 39 sampling stations in the St. Lawrence River near Cornwall, Ontario (Figure 1). The sampling stations were located primarily along the banks of the river and along the nearshore areas of the islands above and below specific discharge sources to the river.

A Ponar grab, which enclosed an area of 516 cm², was used to sample the benthic fauna. Each sample was sieved in a stainless-steel screen pail containing a No. 30 (U.S. Standard Sieve Series) mesh screen (aperture 0.60 mm); the remaining sediment, debris and organisms were then placed into labelled one-litre bottles and stored on ice. These samples were transported to a field laboratory where the organisms were sorted live from the sediment and debris in white enamel trays using forceps. The invertebrates were then placed in 30 ml bottles and preserved with 80% ethanol, except oligochaetes which were preserved with 10% formalin (4% formaldehyde).

The benthic invertebrates were taxonomically identified by Ronald W. Griffiths and Robert Buran of Aquatic Ecostudies Limited, Kitchener, Ontario. Generally, the insects, crustaceans and molluscs were identified to the generic level, mature oligochaetes and polychaetes to the specific level, and other invertebrates to class (see Appendix 1 for a list of the major taxonomic references). All organisms were identified except where large numbers of oligochaetes or chironomids were present. In samples with a large number of worms, all individuals which could be identified under a dissecting microscope, eg. Stylodrilus herringianus, Spiroserma ferox, Potamothrix moldaviensis, etc., were enumerated and removed from the sample. The remaining individuals were sorted into two groups: hair chaete present and hair chaete absent. A random sample of not less than 20% of the individuals from each group, up to a maximum of 100 individuals, was removed from each group for identification. Similarly, in samples with a large number of midges, all individuals which could be identified under a dissecting microscope, eg. Chironomus, Procladius, Cryptochironomus, etc., were enumerated and removed from the sample. The remaining individuals were sorted into three groups: Chironominae,

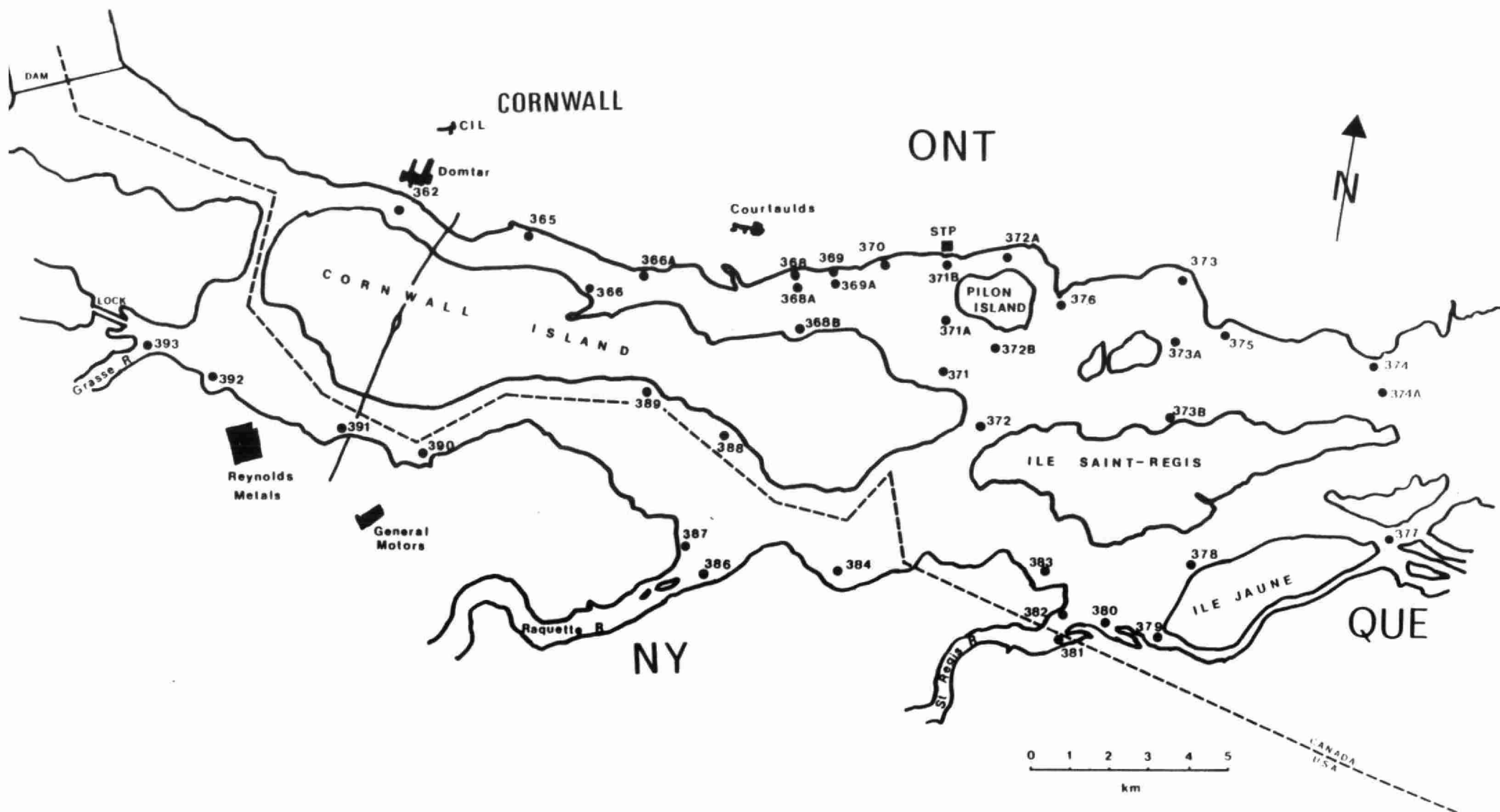


Figure 1: Locations of sampling sites in the St. Lawrence River, near Cornwall, July 1985.

Tanypodinae, Orthocladiinae (including Diamesinae). A random sample of not less than 10% of the individuals from each group, up to a maximum of 50 individuals, was removed from each group for identification. The subsamples of worms and midges were mounted on glass slides in a clearing medium, left for 24 h at 60°C, then identified under a microscope.

In conjunction with the invertebrate sampling, a Shipek grab was used to collect surficial sediment samples for grain size analysis and chemical analyses. At each sampling station, about the top 3 cm of sediment from three Shipek samples were composited. Sub-samples of this composite were placed in 500 ml wide-mouth glass jars with pulp-lined screw caps (heavy metals and grain size analysis), or in solvent-rinsed 500 ml jars with foil-lined caps (organochlorine pesticides and PCB analysis). The field sampling methods are described in detail in OMOE (1979).

The sediment samples were submitted to the Ontario Ministry of the Environment's main laboratory in Toronto for analysis of total metals (Fe, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn), nutrients (total Kjeldahl-N, total-P), oils and grease (solvent extractables), organochlorine pesticides (Aldrin, BHC's, Mirex, Chlordane, Oxychlordane, Dieldrin, Endrin, Thiodan, DDT and metabolites, Heptachlor, Heptachlor epoxide, Hexachlorobenzene), Polychlorinated Biphenyls (PCB's), and grain size. Grain size analysis of the larger particle fractions was done by dry-sieving, while analysis of the less than 1mm fraction was done by a laser particle size analyzer. All chemical analyses were conducted according to the Ministry's Handbook of Analytical Methods (OMOE 1983).

Data Analysis:

Non-hierarchical classification analysis (Gauch 1982) was used to split the sampling stations into groups with similar species assemblages (ie. benthic communities). Classification analysis is a multivariate technique of partitioning objects (eg. sampling stations) into groups based on a set of descriptors (eg. species abundance). The analysis was conducted using the $\ln(x+1)$ transformed mean species abundance as descriptors of the sampling stations. Each sampling station therefore was represented by a single sample.

The non-hierarchical classification analysis was conducted using the Fortran program Compclus (Gauch 1979). The analysis was conducted 20 times using the percent difference measure of dissimilarity. Because the analysis randomly assigns stations as groups centres, a different solution was obtained with every run. A comparison of these equally-probable solutions was made to determine whether the defined community groups were ecologically real (ie. the stations within a group were actually clustered together in multivariate space and therefore had similar species assemblages) or were an artifact of the analysis (ie. groups were simply imposed on the data). The classification outcome that approximated the average station composition of the community groups was used for this report.

Discriminant analysis (Legendre and Legendre 1983) was used to relate the defined benthic communities to the measured physical and chemical sediment variables in order to interpret the communities in terms of environmental quality. Discriminant analysis is a multivariate technique used to distinguish known groups of objects (eg. benthic communities) on the basis of a series of measured quantitative descriptors (eg. physicochemical variables). Because the physicochemical variables were standardized prior to the analysis, the resultant discriminant axes represent discriminant functions (Legendre and Legendre 1983), which are simply linear combinations of the physicochemical variables that maximize the variance between the benthic communities. An ecological interpretation of each axis was made based on the correlation coefficients (r) between the axis and the original physicochemical variables.

The results of discriminant analyses are typically "good" (ie. the amount of "explained variance" is high). However, the analysis does not imply that a cause-and-effect relationship exists, only that a correlation exists between the biologically-defined communities and a linear combination of the physicochemical variables (ie. the discriminant functions). Although the amount of "explained variance" may be high, this does not mean that the analysis is ecologically interpretable because there is no relationship between "explained variance" and "ecological meaning" (Gauch 1982). The interpretation of the discriminant analysis therefore must be done with an understanding of the mathematical algorithm, the biology (life-histories) of benthic invertebrates, the

ecological interrelationships between the aquatic invertebrates, and the interactions between the physicochemical variables.

Thirteen physicochemical variables were used to discriminate between the benthic communities: Grain size represented the physical characteristics of the sediments; iron, arsenic, cadmium, copper, chromium, mercury, nickel, lead, and zinc represented the metal contamination; phosphorus and nitrogen represented the nutrient status; and solvent extractables represented the degree of oil and grease contamination of the sediments at a station. Specific pesticides variables could not be used because the majority of values were below the detection limits of the analytical procedures.

To satisfy statistical requirements of the analysis (see Green 1979), all variables were log-transformed with the exception of grain size, which did not require transformation. The analysis was conducted using computer programs from the Statistical Analysis System (SAS 1982). Since discriminant analysis is particularly susceptible to rounding errors (Green 1979), double precision was used during the analysis.

In addition to the discriminant analysis, the environmental quality represented by the benthic communities was also evaluated by examining the structural and functional organization and the species composition of the communities. Community structure was represented by species richness (number of taxa per sample) and total invertebrate density, whereas the functional organization was represented by the relative abundance of invertebrates in each of the functional-feeding groups, ie. scrapers, collector-gatherers, collector-filterers, shredders and predators (Merritt and Cummins 1984). Studies have shown that characteristic changes occur in the species richness, invertebrate density and species dominance in response to specific types of pollutants and general environmental conditions (eg. Hynes 1960; Saether 1979; Winner et al. 1980; Wiederholm 1984; Krieger 1985; Lauritsen et al. 1985; Wallace et al. 1986). Pollution, especially when caused by organic or nutrient enrichment, affects the structure of invertebrate communities by altering the flow of energy through the community (Wuhrmann 1974). Vannote et al. (1980) proposed that the resident invertebrate functional-feeding groups of Cummins (1984) can be used to indirectly measure the overall energy

dynamics in the environment. They showed that the functional organization of invertebrate communities was characteristic of the physical attributes of the habitat. Thus the presence of various types of pollution can be ascertained by comparing the functional organization of a community with that predicted from the physical attributes of the environment (eg. Rabeni et al. 1985; Mayack and Waterhouse 1983). An examination of structural and functional organization and species composition of the communities therefore can be used to elucidate the environmental quality conditions reflected by the invertebrate communities.

Since invertebrate species have specific habitat requirements with respect to sediment grain size, current speed, etc. (Hynes 1970), different benthic communities can be expected in areas of the river with different physical characteristics. Therefore, applying Occam's razor, physical and other "non-pollution" variables were given priority to explain the difference in the species composition between communities. Subsequently, the chemical and other "pollution" variables were used to account for these differences. To help evaluate whether the observed sediment concentration of a chemical variable was sufficient to affect the invertebrate fauna, the mean concentrations of the chemical variables associated with each benthic community were compared with the U.S. EPA's Guidelines for Pollutational Classification of Great Lakes Harbour Sediments (IJC 1982). Only when the mean concentration of a variable indicated that the sediments were heavily polluted, was it considered to possibly have had an effect on the abundance of invertebrates.

Each benthic community therefore was interpreted to represent a different degree of environmental quality with respect to specific physicochemical variables. Zones of varying environmental quality were delineated based on the distribution of the benthic communities in the river and then related to specific waste sources.

RESULTS AND DISCUSSION

Benthic Communities:

Seventy-eight macroinvertebrate taxa were identified from the 39 sampling stations in the study area (Appendix 2). Based on their species composition, the classification analysis split the sampling stations into twelve groups, each representing a different assemblage of invertebrates or benthic community. The taxonomic composition of the communities is shown in Tables 1 and 2.

Six of the communities (labelled A-F) were represented by only a single sampling station (Figure 2). Communities B, C, D, and E were found at the mouths of the three main tributaries that flow into the St. Lawrence River from New York State, community F just downriver of the St. Regis River, and community A on the north shore of the St. Lawrence River near an oil storage depot. Because site-specific communities reflect unique local environmental conditions, data from sampling stations associated with communities A-F were not used in the subsequent discriminant analysis. The environmental quality represented by these communities was estimated directly from the species composition and sediment data.

The other six communities (labelled 1-6) occurred at 3 or more sampling stations throughout the study area (Figure 2): Community 1, characterized by the numerical abundance of the midges, Chironomus and Phaenopsectra, the amphipod, Gammarus, the clam, Pisidium, and the worm, Limnodrilus hoffmeisteri, occurred upriver of Domtar Fine Papers on the north shore of the St. Lawrence River, on the north shore of Cornwall Island, and upriver of the St. Regis River on the south shore of the St. Lawrence River. Community 2, characterized by high species richness and the lack of any numerically abundant species, was found primarily throughout the south channel of the river. Community 3, characterized by the abundance of Gammarus, Chironomus and the isopod, Asellus, was found primarily in the north channel of the river between Domtar Fine Papers Ltd. and Pilon Island, while community 6, characterized by the abundance of Pisidium, occurred downriver of the Cornwall sewage

Table 1: Species composition (mean number per 516 cm²) of benthic communities 1-6 in the St. Lawrence River near Cornwall, July 1985. P denotes a mean density of less than 1 per sample.

	Benthic Community					
	1	2	3	4	5	6
AQUATIC CATERPILLARS:						
Pyrilidae	P	P	2.1	P	P	
BEETLES:						
Elmidae	P			P		
Gyrinidae		P	P			
CADDISFLIES:						
Brachycentrus	2.5		1.7			
Hydroptila	P	P				
Ceraclea	1.0	P				
Mystacides		P				P
Oecetis	P	P	P	P		P
Triaenodes	P		P			
Phylocentropus		P		P	P	P
MAYFLIES:						
Brachycercus		P				
Caenis	P	P		P		
Hexagenia		P	P	P		
TRUE FLIES:						
Ceratopogonidae	1.0	P	P	P		P
Chironomus	180.5	18.7	31.0	1.0	30.3	12.0
Cladopelma		P	P	P	1.0	
Cryptochironomus		1.0	1.1		P	
Dicrotendipes	1.4	1.2	P	P	P	
Glyptotendipes		P				
Harnischia		P	P			
Microtendipes	2.2	1.8	1.6	P	P	3.3
Parachironomus	1.2	P	P		P	
Paralauterborniella	6.9	P				1.4
Paratanytarsus	4.6	2.8	2.3	P		P
Paratendipes	2.9	P				P
Phaenopsectra	26.3	3.9	5.3	P	P	P
Polypedilum	1.3	6.2			1.3	P
Rheotanytarsus	5.9	1.2	1.8	P	P	P
Stictochironomus						
Tanytarsus		1.4	P			2.0
Tribelos	4.1	4.9	1.8	P	P	1.6
Cricotopus/Orthocladius	9.1	P	4.1	P	2.0	P
Nanocladius			P	P	P	
Psectrocladius	P	1.2		P		P
Ablabesmyia			P			
Clinotanytus		1.0		P	P	P
Procladius	3.5	8.1	P	P	8.5	P
CRUSTACEANS:						
Gammarus	111.5	6.4	188.3	17.8	138.3	17.4
Asellus	2.1	P	33.0	20.9	37.4	7.0

Table 1: continued.

	Benthic Community					
	1	2	3	4	5	6
CLAMS:						
Pisidium	35.7	8.6	11.9	3.1	18.1	31.4
Sphaerium	1.5	2.8	4.0	1.6	2.9	10.1
Unionidae	P	P	P		P	P
SNAILS:						
Ferrissia		P				P
Bithynia	16.8	2.4	15.2	2.2	8.6	18.3
Amnicola	11.3	10.3	6.8	2.0	19.7	12.1
Probythinella		P		P	P	
Somatogyrus	1.7	P			P	P
Fossaria	1.6	6.1	1.4	P	3.2	P
Lymnaea	P	P		P	P	
Pseudosuccinea			P			
Stagnicola		P				P
Physa	4.6	3.4	1.2	1.0	7.9	P
Gyraulus	2.4	P	1.2	P	2.7	P
Helisoma		1.2	P	P	1.0	P
Promenetus		P			P	
Goniobasis	P	P			1.0	
Valvata	P	P	1.4	P	1.7	4.2
Campeloma	P				P	
LEECHES:						
Erpobdellidae	P	P	P		P	P
Glossiphonidae	2.6	P	P	P	2.3	1.5
POLYCHAETES:						
Manayunkia speciosa		P				
WORMS:						
Lumbricidae	1.1	2.9	P	P		1.3
Stylodrilus herringianus		P	P			P
Stylaria		P				
Aulodrilus americanus		P				
Ilyodrilus templetoni	P	1.1		P	1.1	P
Isochaetes freyi						
Limnodrilus cervix				1.2		
L. hoffmeisteri	31.5	8.1	6.4	42.9	41.3	1.7
L. udekemianus				1.5	1.7	
Potamotheix moldaviensis		P				
Quistadrilus multisetosus		1.3	P	P	4.9	P
Spirosperma ferox	9.4	4.3	1.1	P	P	7.7
PROBOSCIS WORMS:						
Prostoma	P	1.0	P		P	P
NEMATODES	5.5	P	2.0	P	1.0	1.3
FLATWORMS	P	P	3.4	P	2.4	1.6
MEAN NUMBER OF TAXA	22.8	19.7	16.2	10.7	17.7	18.0
MEAN DENSITY OF ORGANISMS	501.5	122.5	339.8	105.7	347.5	147.8

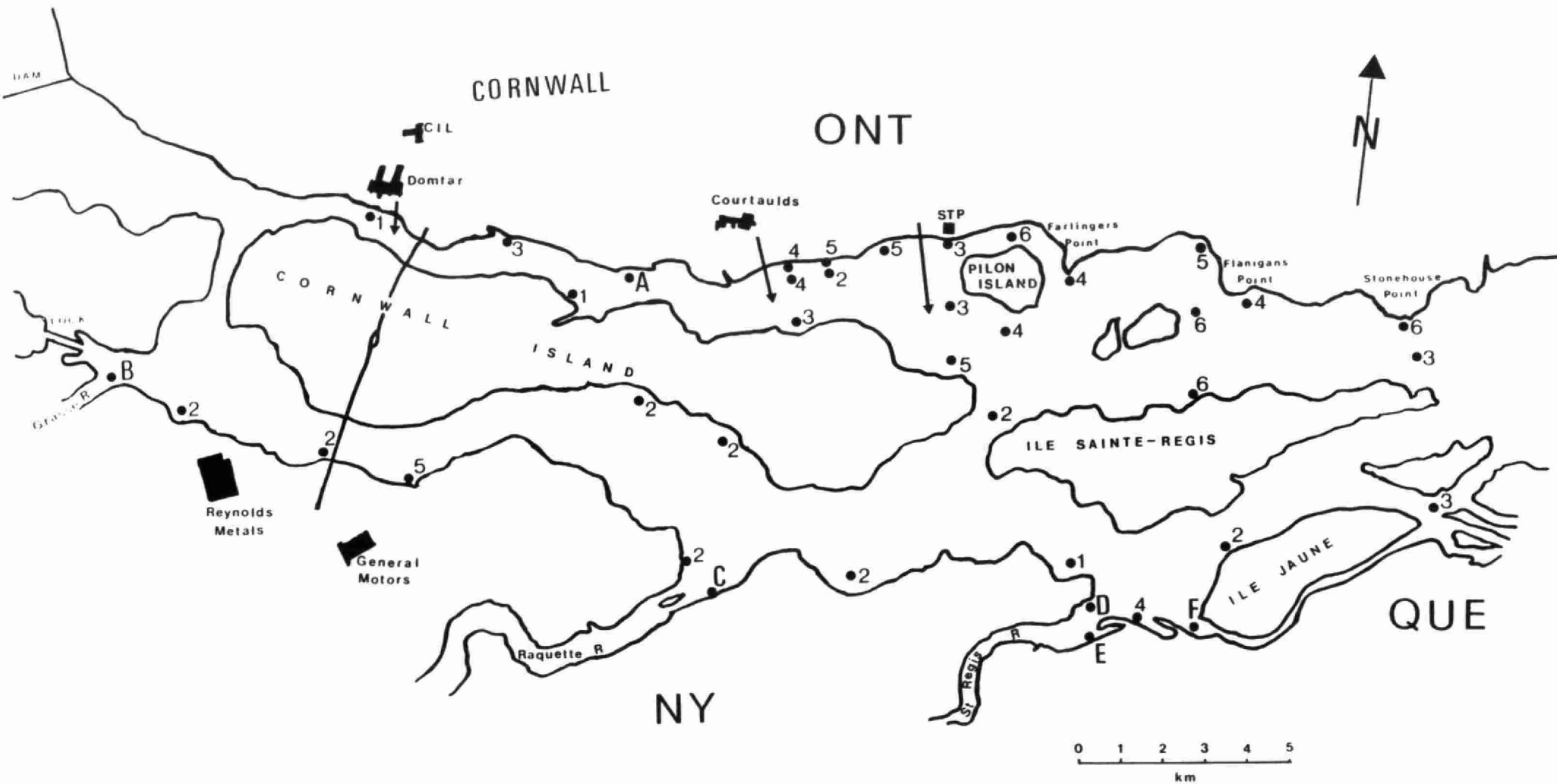
Table 2: Species composition (mean number per 516 cm²) of benthic communities A-F in the St. Lawrence River near Cornwall, July 1985. The station location is noted below each community type. P denotes a mean density of less than 1 individual per sample.

	Benthic Community					
	A 366A	B 393	C 386	D 382	E 381	F 379
AQUATIC CATERPILLARS:						
Pyralidae						
BEETLES:						
Elmidae		2.0		1.0	1.0	P
Gyrinidae						
CADDISFLIES:						
Brachycentrus						11.0
Hydroptila						
Ceraclea						1.5
Mystacides						
Oecetis		2.0				
Trianaodes						
Phylocentropus		P	1.0	1.0		
MAYFLIES:						
Brachycercus					P	
Caenis		P				
Hexagenia				1.5		
TRUE FLIES:						
Ceratopogonidae		P	1.5	3.0		P
Chironomus	40.0		3.0	5.5		
Cladopelma						
Cryptochironomus			3.0	2.0	8.0	
Dicrotendipes		4.0	3.0	3.0		
Glyptotendipes		1.0	3.0	2.0		
Harnischia				3.0		
Microtendipes						1.0
Parachironomus		1.0				
Paralauterborniella						
Paratanytarsus		1.5				
Paratendipes						
Phaenopsectra	8.0					3.5
Polypedilum		4.0		3.0		3.5
Rheotanytarsus						11.0
Stictochironomus			3.0		2.0	
Tanytarsus				7.0	1.0	
Tribelos						
Cricotopus/Orthocladius		1.5			1.0	7.5
Nanocladius						
Psectrocladius						
Ablabesmyia				3.0		2.0
Clinotanypus		1.5		1.0		
Procladius		5.0	3.0	2.0	P	
CRUSTACEANS:						
Gammarus		6.5			P	10.5
Asellus				1.0		

TABLE 2: continued.

	Benthic Community					
	A	B	C	D	E	F
	366A	393	386	382	381	379
CLAMS:						
Pisidium	24.0	P		1.0		5.0
Sphaerium		P	1.0	1.0		9.5
Unionidae		2.5		P		1.5
SNAILS:						
Ferrissia						
Bithynia		1.0			P	1.5
Amnicola		P	5.0	5.5	P	6.0
Probythinella						
Somatogyrus			2.0			1.0
Fossaria						P
Lymnaea						
Pseudosuccinea		P				
Stagnicola						
Physa						
Gyraulus						
Helisoma						
Promenetus						
Goniobasis						10.0
Valvata		P				P
Campelema						
LEECHES:						
Erpobdellidae						
Glossiphoniidae				P	P	
POLYCHAETES:						
Manayunkia speciosa						
WORMS:						
Lumbricidae		P	2.5			
Stylodrilus herringianus		1.5				P
Stylaria				1.0		
Aulodrilus americanus			2.0	8.5		
Ilyodrilus templetoni			P			
Isochaetes freyi			3.0		5.0	
Limnodrilus cervix						
L. hoffmeisteri	8.0	7.0	3.0	14.5	4.0	
L. udekemianus						
Potamotheix moldaviensis		2.0				
Quistadrilus multisetosus		P				
Spirosperma ferox		13.5				1.5
PROBOSCIS WORMS:						
Prostoma		P				
NEMATODES	8.0					P
FLATWORMS						
MEAN NUMBER OF TAXA	3.0	18.5	10.5	15.0	8.0	17.5
MEAN DENSITY OF ORGANISMS	88.0	64.0	39.5	71.5	25.0	90.5

Figure 2: Distribution of benthic invertebrate communities in the St. Lawrence River, near Cornwall, July 1985.



treatment plant (STP) and from the Colquhoun Islands to Stonehouse Point in the north channel. Community 4, characterized by the abundance of L. hoffmeisteri and Asellus, and community 5, characterized by the abundance of Gammarus, L. hoffmeisteri, Asellus and Chironomus, occurred along the north shore of the river from Courtaulds to the STP and from Farlinger's Point to Flanagan's Point, and along the south shore of Pilon Island.

Environmental Quality Evaluation:

The discriminant analysis of communities 1-6 suggests that the six communities were associated with different environmental conditions (Figure 3). The first discriminant axis (DA I) explained 67.4% of the total variation and showed a significant linear correlation with As, Hg, Pb, Zn, oils and grease, and TKN ($r > 0.40$; $p < 0.02$) (Table 3). This axis indicates that community 4 occurred in sediments with relatively high concentrations of metals (particularly As, Hg, Pb and Zn), oils and grease and TKN, whereas communities 1 and 2 occurred in sediments with relatively low concentrations of metals, oils and grease and TKN and communities 3, 5 and 6 occurred in sediments with intermediate levels of these variables. Table 4 shows that the mean concentrations of metals, oils and grease and nutrients in sediments associated with community 4 were generally higher than in sediments associated with any other community. Using the US EPA's Guidelines for Pollutational Classification of Great Lakes Harbor Sediments (IJC 1982), sediments associated with community 4 were considered heavily polluted with respect to Zn, oils and grease, TP and TKN (Table 4). In contrast, the mean concentrations of metals, oil and grease and nutrients in sediments associated with communities 1 and 2 were the lowest measured. However, sediments associated with community 2 were still considered heavily polluted with respect to TP. DA I therefore suggests that the difference in the species composition of the communities may be related to the sediment concentrations of Zn, oils and grease and TKN.

The second discriminant axis explained only 19.1% of the total variation and correlated poorly with the measured environmental variables (Table 3). It separated community 1 from 2, community 3 from 4 and community 6 from 5 (Figure 3). DA II suggests therefore that the

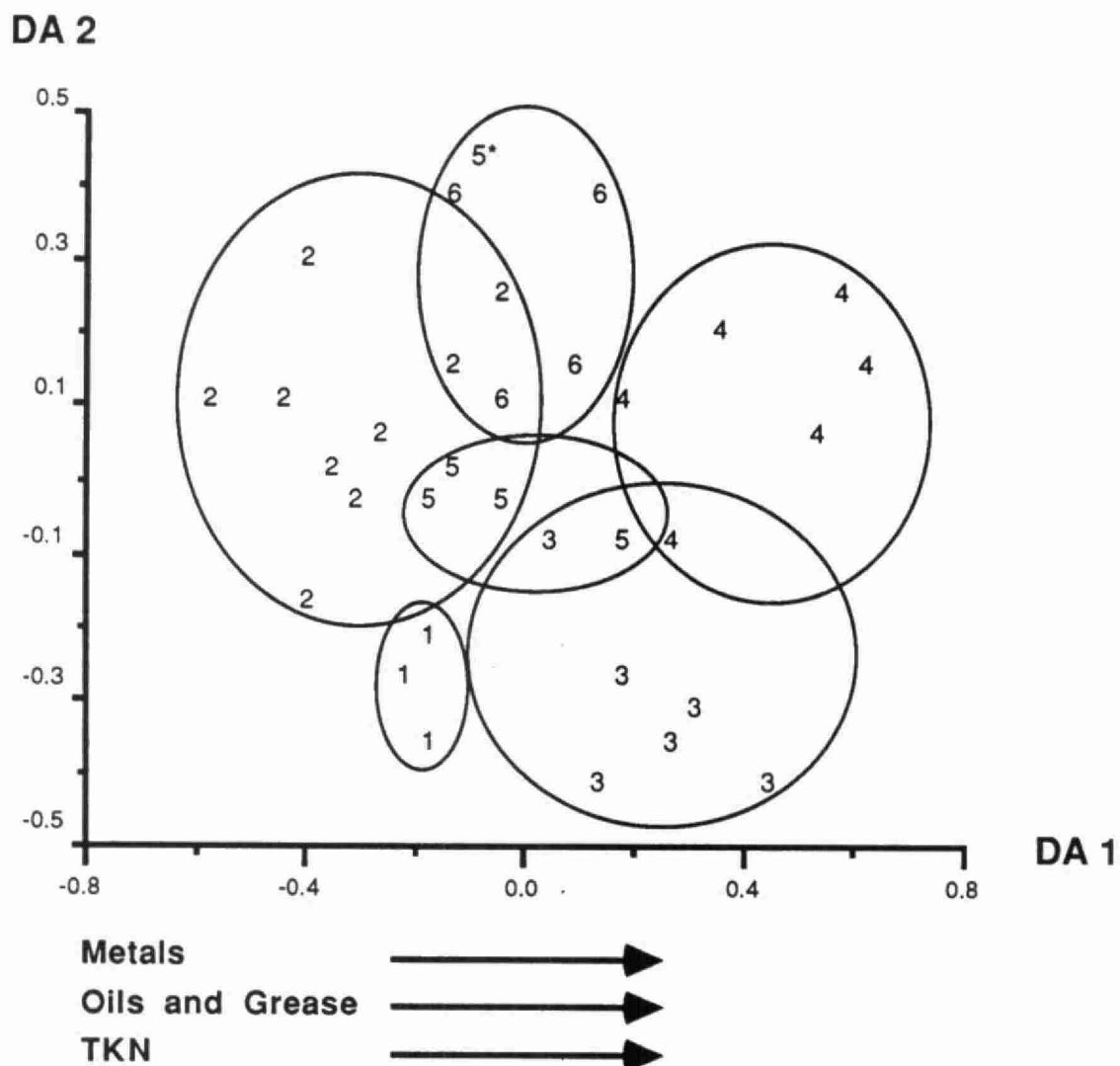


Figure 3: Plot of benthic invertebrate communities in discriminant space as defined by the first two discriminant functions.

* means community is probably misclassified

Table 3: Correlations (r) between the physicochemical variables and the first two discriminant functions.

Physicochemical Variables	Discriminant Functions	
	1	2
Fe	0.22	-0.13
As	0.57	0.00
Cd	0.34	0.00
Cr	0.27	-0.04
Cu	0.40	-0.03
Hg	0.55	0.37
Ni	0.38	0.21
Pb	0.47	0.10
Zn	0.48	0.16
Oils and Grease	0.46	0.17
Total-P	0.23	0.21
Total Kjeldahl-N	0.56	0.12
Grain Size	0.13	0.23

Table 4: Mean values of physicochemical sediment variables associated with benthic communities 1-6 in the St. Lawrence River near Cornwall, July 1985. All units are expressed as mg/kg unless otherwise stated.

	BENTHIC COMMUNITY					
	1	2	3	4	5	6
Fe (g/kg)	11.11	12.57	14.37	14.00	14.14	10.74
As	1.86	2.27	4.06*	4.14*	3.46*	2.69
Cd	0.30	0.36	0.53	0.59	0.48	0.46
Cr	24.81	29.67*	34.36*	38.58*	35.64*	30.12*
Cu	12.46	22.27	36.87*	36.45*	32.59*	22.58
Hg	0.04	0.08	0.20	0.86	0.46	0.17
Ni	8.02	10.88	14.34	17.32	15.21	12.05
Pb	8.21	14.10	20.79	39.93	23.08	17.51
Zn	34.80	74.80	92.84*	362.43**	144.20*	89.50
Oils and Grease (g/kg)	0.51	1.19*	1.67*	3.22**	2.12**	1.63*
Total-P (g/kg)	0.58*	0.70**	0.77**	0.75**	0.88**	0.80**
TKN (g/kg)	0.64	1.10*	2.39**	2.30**	1.87*	1.73*
Grain Size (phi)	2.5	3.1	3.2	3.3	3.6	3.3

Based on the US EPA Guidelines for Pollutational Classification of Great Lakes Harbour Sediments (IJC 1982):

- * means that the sediment is considered moderately polluted,
- ** means that the sediment is considered heavily polluted.

difference in the species composition between these pairs of communities was not related to sediment concentrations of metals, oil and grease or nutrients or sediment grain size but to some unmeasured variable(s), which was probably non-linearly related to the measured physicochemical variables. One possible variable was the density of aquatic macrophytes. Aquatic macrophytes are common throughout the study area (Owen and Wile 1975). Denser growths of aquatic plants were observed at the sites associated with communities 1 or 3 than sites associated with communities 2 or 4. (E. Law, Ministry of the Environment, personal communication). The high density of Gammarus and Chironomus in communities 1, 3 and 5 suggests that the plant densities at these sites were greater than at sites with the other communities.

DA I therefore can be interpreted in terms of environmental quality and DA II in terms of habitat characteristics. The analysis suggests that community 4 reflected degraded environmental quality conditions with respect to Zn, oils and grease and TKN, relative to communities 1 and 2, which represented the background or reference conditions. Communities 3, 5 and 6 represented intermediate but impaired environmental quality conditions. The density of aquatic plants, or a related factor, appeared to influence which community occurred at a site within each of the different types of environmental conditions.

An examination of the structure, functional organization and taxonomic composition of the communities supports these results and provides additional information. Species richness (mean number of taxa per sample) was greatest for communities 1 and 2 (Table 1). The species richness of communities 3, 5 and 6 was slightly lower, whereas the species richness of community 4 was half that of communities 1 and 2. Since grain size was similar among communities, the reduced species richness of community 4 was probably the result of impaired environmental quality conditions at those sites. The relatively poor representation of molluscs in community 4 suggests an effect of metal toxicity on the biota (Henderson 1949). The concentrations of heavy metals, especially Zn and Hg, in the sediments were greater than those of the other communities (Table 4). Furthermore, the poor representation of chironomids, numerical dominance of the pollution-tolerant worm, L. hoffmeisteri and the presence of the pollution-tolerant worms, L. udekemianus and L.

cervix indicate gross organic matter enrichment and very poor oxygen conditions. The sediments at most stations were described as black ooze with a high detritus content. Woods chips were noted at some stations, while the sediments at others were noted to have an organic or sulphurous odour (Appendix 3). The composition of community 4 therefore reflected the most degraded environmental conditions of the communities.

The mean density of invertebrates in communities 1, 3 and 5 was two to four times greater than in communities 2, 4 and 6 (Table 1). As noted previously, this difference was probably related to the density of aquatic macrophytes, which provide a source of food, shelter from fish predation, and a stable habitat for invertebrates. The densities of Gammarus, Chironomus, Gyraulus and Bithynia are particularly good indicators of macrophyte abundance since these species utilize the surfaces of plants as a habitat. The high densities of invertebrates, widespread occurrence of aquatic macrophytes (Owen and Wile 1975) and high sediment phosphorus concentrations indicated that eutrophic conditions prevail throughout the study area. The numerically dominant invertebrates found in the study, Chironomus, Gammarus, Asellus, Bithynia and L. hoffmeisteri, are all characteristic of eutrophic waters and thus are tolerant of low oxygen concentrations, organic enrichment, warm temperatures, and turbidity.

The functional organization of communities 1 and 2 (Figure 4) was typical of large rivers (Vannote et al. 1980): Collector-gatherers dominated the communities and collector-filterers and scrapers were well represented. The increased proportion of shredders, mainly Gammarus and Asellus, in communities 3 and 5, relative to community 1, and in community 4, relative to community 2, indicated that the environmental quality conditions had been impaired as a result of accumulations of coarse particulate organic matter (CPOM) on the sediments, which caused a shift in the energy dynamics of the communities towards heterotrophy. The increased proportion of collector-filterers in community 6 also indicated a shift towards heterotrophy, but as a consequence of increased concentrations of fine particulate organic matter (FPOM) in the water column. Thus, the impairment reflected by community 6 was relatively less.

In summary, these analyses suggest that communities 3, 4 and 5

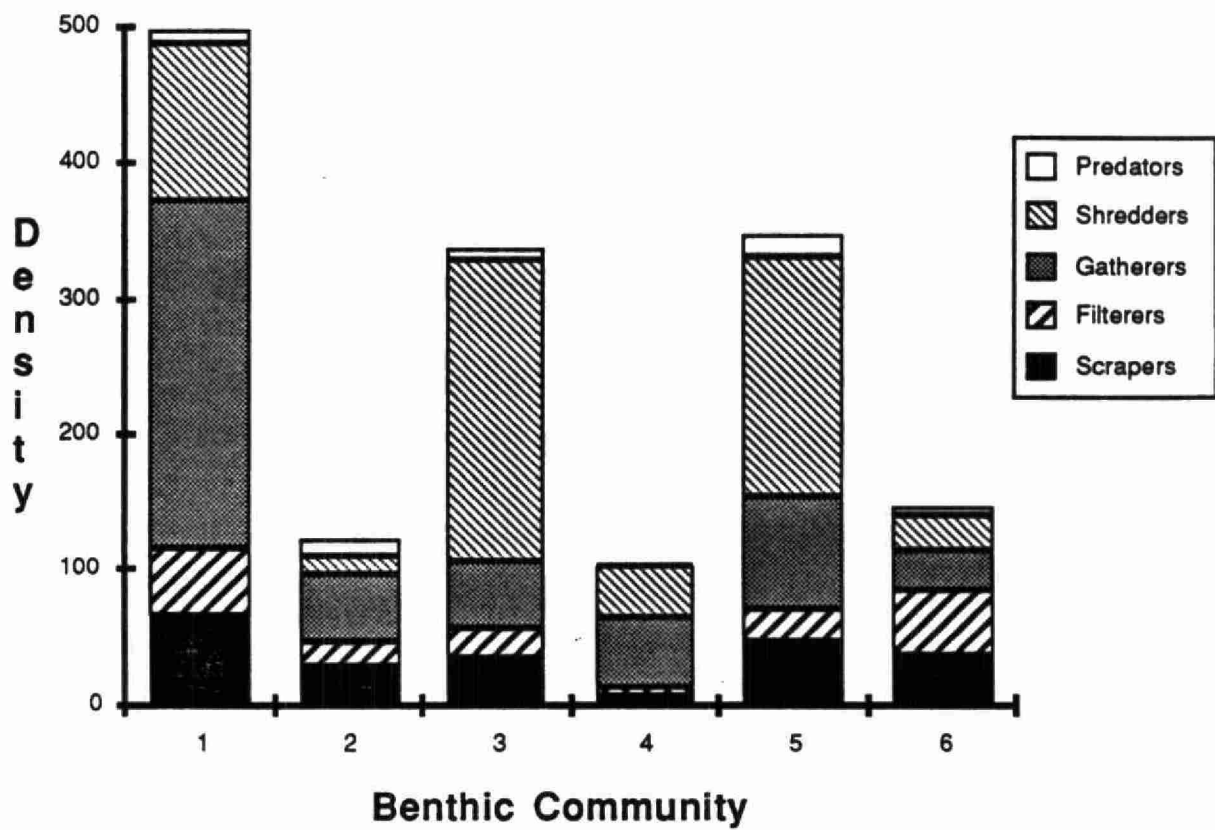


Figure 4: Abundance of invertebrates (number per grab) by functional-feeding group in benthic communities 1-6.

reflected impaired environmental quality conditions primarily as a result of CPOM accumulations. In addition, community 4 indicated a further degradation in environmental quality related to low dissolved oxygen concentrations, organic enrichment, and possibly metal toxicity. Communities 1 and 2 reflected unstressed, but eutrophic conditions, while community 6 inferred a slight impairment of environmental quality.

The composition of communities B, C, D, and E, which occurred at the mouths of the three main tributaries to the St. Lawrence River (Figure 2), was indicative of less-productive, unstressed lotic conditions. The density of invertebrates was low (25-72 invertebrates per grab versus 120-500 invertebrates per grab for communities 1 and 2), and few species were numerically abundant (Table 2). The functional organization of the communities was similar to community 2: Collector-gatherers dominated the communities, but all groups were evident (Figure 5). Pollution-sensitive species such as the worms, Potamothrix moldaviensis, Isochaetes freyi, Stylodrilus herringianus and Aulodrilus americanus and the chironomids, Stictochironomus and Tanytarsus, were common in the communities. The low density and species richness of community E at the mouth of the St. Regis River was probably related to the coarse sand substrate ($\phi=1.5$) of the area and not to pollution.

Although concentrations of metals, oils and grease and nutrients in the sediments associated with communities B-E were the lowest observed in the study (Table 5), the sediments at the mouth of the Grasse River were still considered to be moderately polluted with respect to Cr, while the sediments at the mouth of the St. Regis River were considered to be moderately polluted with respect to Zn. However, there was no evidence that the invertebrate communities were affected by these metals.

Similarly, the composition of community F indicated unstressed environmental conditions. The increased density of collector-filterers and scrapers relative to communities B-E (Figure 5) was a consequence of the hard, compact sediments that occurred in the area. Although the sediments were considered to be moderately polluted with Fe, As and Cr (Table 5), no effect was evident on the species composition.

In contrast, the composition of community A reflected grossly

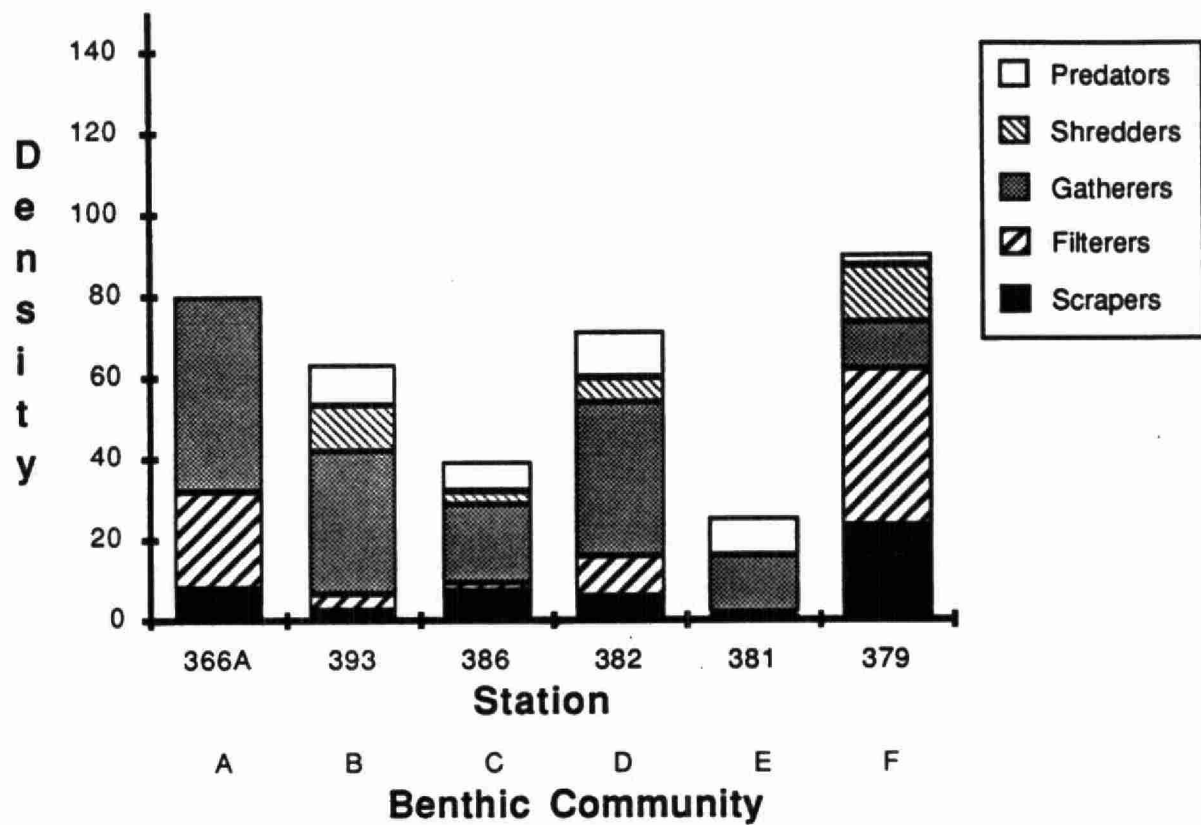


Figure 5: Abundance of invertebrates (number per grab) by functional-feeding group in benthic communities A-F.

Table 5: Mean values of physicochemical sediment variables associated with benthic communities A-F in the St. Lawrence River near Cornwall, July 1985. Station locations are noted below each community. All units are expressed as mg/kg unless otherwise stated.

	BENTHIC COMMUNITY					
	A 366A	B 393	C 386	D 382	E 381	F 379
Fe (g/kg)	11.00	11.00	9.80	13.00	5.50	25.00*
As	2.37	1.48	1.21	1.93	0.41	3.08*
Cd	0.37	0.21	0.25	0.37	0.10	0.10
Cr	29.00*	27.00*	19.00	17.00	6.20	55.00*
Cu	23.00	17.00	9.70	9.50	1.0	24.00
Hg	0.90	0.05	0.06	0.05	0.01	0.01
Ni	12.00	9.80	5.90	7.80	2.20	19.00
Pb	25.00	10.00	11.00	16.00	2.30	6.50
Zn	58.00	58.00	82.00	92.00*	14.00	79.00
Oils and Grease (g/kg)	2.94**	0.70	0.58	0.67	0.11	0.01
Total-P (g/kg)	0.70**	0.66**	0.41	0.62*	0.24	0.78**
TKN (g/kg)	1.50*	1.10*	0.60	1.60*	0.20	0.60
Grain Size (phi)	3.5	2.5	2.5	3.5	1.5	2.5

Based on the US EPA Guidelines for Pollutational Classification of Great Lakes Harbour Sediments (IJC 1982):

- * means that the sediment is considered moderately polluted,
- ** means that the sediment is considered heavily polluted.

polluted conditions. Species richness was poor (3 taxa per sample) and only pollution-tolerant species such as Chironomus, Phaenopsectra and L. hoffmeisteri were common. The sediments were soaked with oil and tar, which probably restricted the fauna to the upper layers of the sediment.

St Lawrence River Environmental Quality Zones:

A summary of the environmental quality interpretations of the benthic invertebrates communities is provided in Figure 6. Based on the distributions of these communities, environmental quality zones were established in the river (Figure 7).

A zone of impaired environmental quality resulting from the accumulation of coarse particulate organic matter extended downriver from Domtar Fine Papers to Pilon Island in the north channel of the river. The CPOM consisted mainly of wood chips and fibers (Appendix 3), indicating that the source of the CPOM originated in the effluent discharge from Domtar's operations. The effect of Domtar's effluent on the invertebrate fauna of the river does not appear to be as serious as the effects typically caused by pulp and paper plants in northern Ontario. However, the invertebrate fauna of the St. Lawrence River is adapted to eutrophic conditions (warm temperatures, poor oxygen concentrations, organic enrichment, turbidity), whereas the faunas of northern rivers are adapted to oligotrophic conditions (cool temperatures, high oxygen concentrations, low organic matter concentrations). Thus, the fauna is tolerant of the water quality conditions in the river that are produced by Domtar's effluent and mainly show a response to the shift in the size of organic particles in the sediments. In northern rivers the fauna shows a response to the reduced oxygen conditions and the accumulations of CPOM.

Mayack and Waterhouse (1983) documented similar changes to the macroinvertebrate fauna of the Saranac River of northern New York state in response to paper mill effluent. The effluent caused few changes in dissolved oxygen, biochemical oxygen demand, temperature or nutrient content of the river but increased the suspended solids concentrations in the water and the accumulation of CPOM on the substrate. A slight

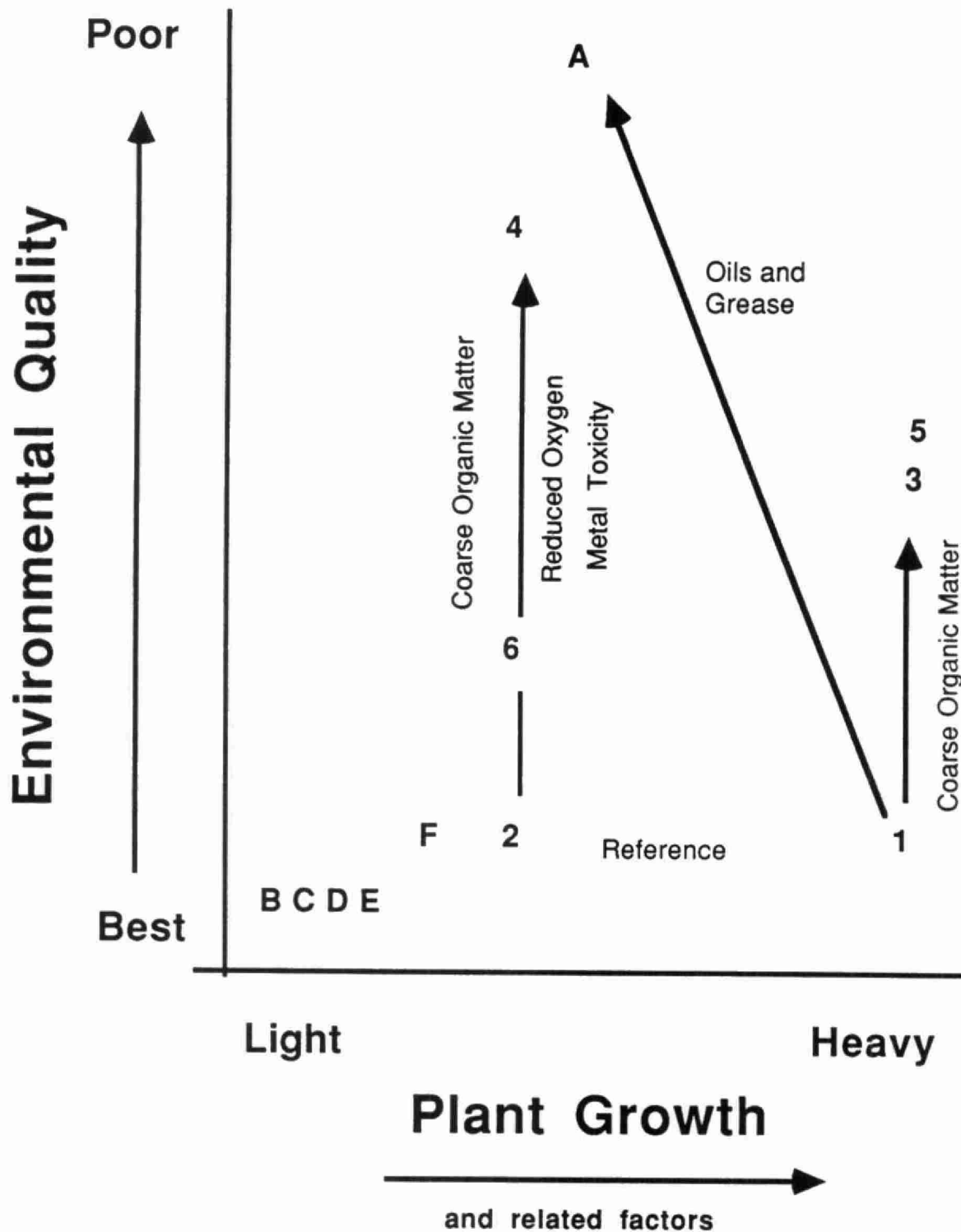
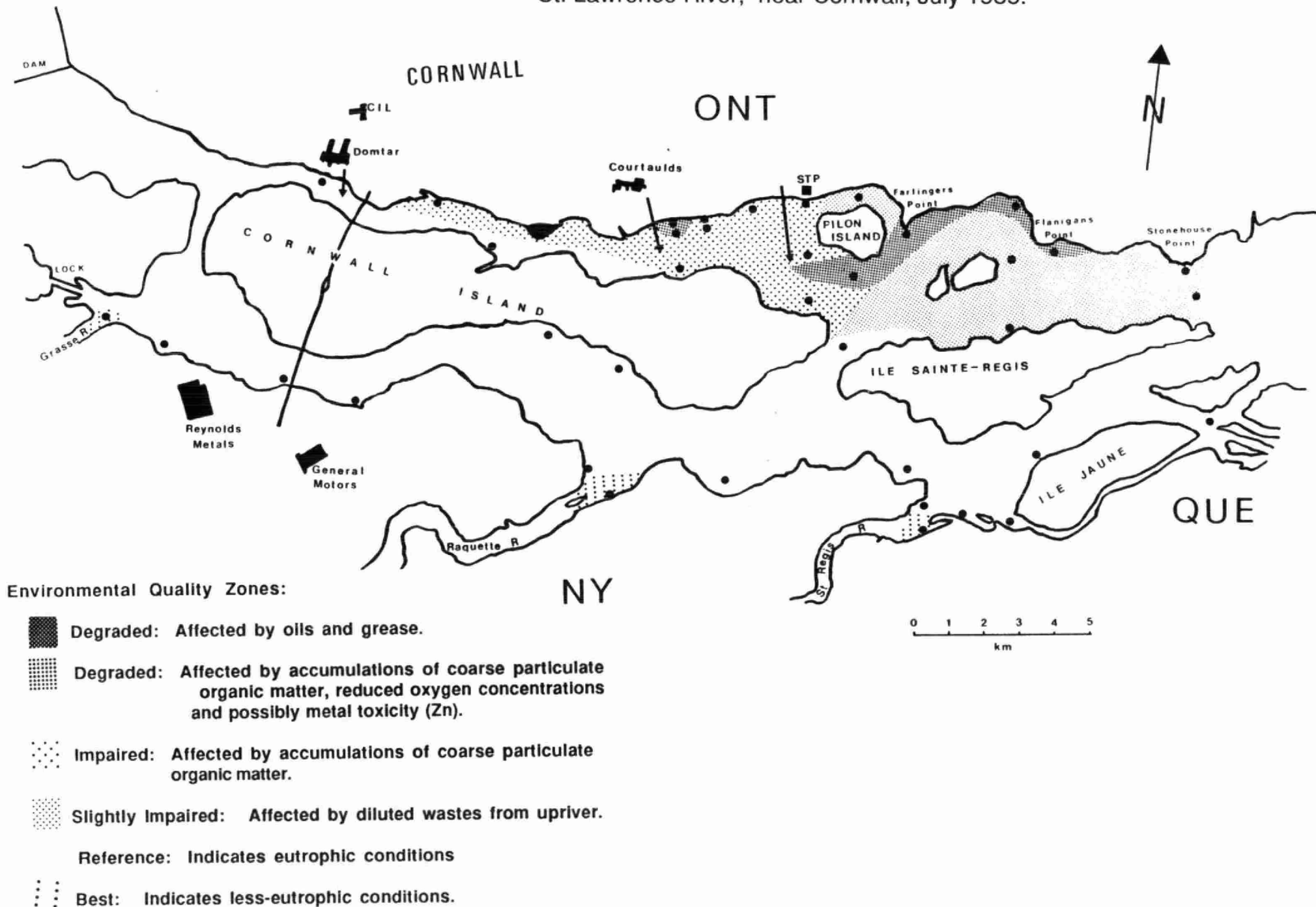


Figure 6: Environmental quality interpretation of benthic invertebrate communities.

Figure 7: Distribution of environmental quality zones in the St. Lawrence River, near Cornwall, July 1985.



reduction in species richness and total invertebrate density, and a shift in the functional organization of the community were observed. These changes are similar to the differences observed between community 1 (reference community) and communities 3 and 5.

Zones of degraded environmental quality resulting from the accumulations of CPOM, reduced dissolved oxygen concentrations and possibly metal toxicity occurred along the north shore of the river in the vicinity of the diffusers of Courtaulds, and downriver from the discharge point of the Cornwall sewage treatment plant (STP) along the south shore of Pilon Island and including the north shore of the river from Farlinger's Point to Flanigan's Point. The small area of impact around the diffusers of Courtaulds, a manufacturer of rayon fiber, suggests that the effluent was rapidly mixed into the river and diluted. However, rayon fibers were found in the sediment samples from both stations 368 and 368A. Except for some chironomids, insects were absent from the area and snails were poorly represented relative to other nearby stations (Appendix 2). This suggests an effect of metal toxicity on the fauna (Henderson 1949; Winner et al. 1980). Henderson (1949) concluded that zinc in the effluent of a rayon manufacturing company in Virginia was the most likely factor affecting the invertebrate fauna of the Shenandoah River. Zinc in quantities as low as 0.2 mg/l have been shown to be lethal to some aquatic animals (Newton 1944). Oligochaetes and chironomids have been found to show avoidance behavior to sediments with zinc concentrations exceeding 1000 mg/kg (McMurty 1984; Wentzel et al. 1977). The sediment concentration of Zn at station 368 was about 3800 mg/kg and the concentration of Zn in the water was 0.44 mg/l (Ministry of the Environment, unpublished). Thus Zn from the effluent of Courtaulds probably has contributed to the local environmental degradation.

Hydrogen sulphide and acidity are two other effluent components, which are produced when rayon is manufactured by the Viscose process (Roetman 1944), that could potentially affect the local fauna. The highly alkaline waters of the St. Lawrence River should neutralize the acidity of the effluent rapidly. However, some sediment samples were noted to have a sulphurous odour, suggesting that hydrogen sulphide may have contributed to the local environmental degradation.

The degraded environmental conditions of the nearshore areas along the south shore of Pilon Island and from Farlinger's to Flanigan's Point along the north shore of the St. Lawrence River, appear to result from poor dissolved oxygen conditions as a consequence of the high organic content of the sediments and possibly from elevated concentrations of Zn and oils and grease. The Zn concentrations in the sediments ranged from 240-520 mg/kg, while the concentration of oils the grease in the sediments were some of the highest measured (2000-6000 mg/kg) (Ministry of the Environment, unpublished). Effluent from the sewage treatment plant is the probable source of the metals, oils and grease and particulate organic matter. The Zn, oils and grease in the effluent probably originate from a number of companies in the Cornwall area.

A large zone of slightly impaired environmental quality was indicated in the north channel of the river from Pilon Island to the downriver end of Ile Sainte-Regis, which marked the end of the study area. In addition to the diluted effluents from Domtar, Courtaulds, and the Cornwall sewage treatment plant, this section of river receives a significant flow of water from the south channel of the river, which helps to further dilute the contaminant loads. The suspended solids from the sewage treatment plant, a source of FPOM, probably accounts for the increased abundance of collector-filterers, mainly clams, in this zone. This section of the river therefore could be considered a recovery zone. Furthermore, it may also represent the area of the river that has recovered from historic waste loadings.

A small zone of degraded environmental quality resulting from oils and grease was observed along the waterfront of Cornwall (station 366a). The station was adjacent to several oil storage tanks and from the degree of contamination of the sediments, it is probable that a number of spills has occurred at this facility.

Eutrophic conditions were indicated throughout the south channel of the river and the region upriver of Cornwall. The nutrient enriched condition of the river is the result of upriver nutrient inputs to the St. Lawrence River. The area was not affected by point source discharges. The single occurrences of communities 3, 4 and 5 along the south shore appear

to be related to the dense macrophyte beds at the sites rather than pollution as was noted in the north channel.

Finally, the best environmental quality conditions were found at the mouths of the Grasse, Raquette and St. Regis Rivers. The composition of the invertebrate communities and the sediment chemistry values suggest that these areas were not affected by upstream point sources. In addition, the composition of the communities, the reduced sediment nutrient concentrations, and the low conductivity of the water indicate that these areas were less eutrophic than the St. Lawrence River proper.

Temporal Changes in the Environmental Quality:

In the summer of 1966, the Ontario Water Resources Commission conducted a benthic invertebrate survey of the St. Lawrence River, which included a number of sampling stations in the Cornwall area (Owen and Veal 1968). This study was conducted prior to the construction of the Cornwall sewage treatment plant, which was completed in the early 1970's. They reported that no invertebrates were found in nearshore samples collected at distances of 1.0, 3.5 and 5.0 km downriver of Domtar's mill operations (approximately stations 365, 368 and 371 in Figure 1) and that the sediments were blanketed with bark and wood chips. At a distance of about 1.6 km downriver of the mill (approximately station 366), where the current velocity prevented the deposition of solids, a community dominated by midges and worms occurred. In contrast, they reported that stations along the south shore of the channel yielded an average of 13 taxa consisting predominantly of pollution-intolerant forms. From these results, they concluded that the nearshore waters along most of the Cornwall waterfront were grossly impaired.

In the present study, invertebrates were found at all stations sampled along the Cornwall waterfront. Although the invertebrate fauna was still impoverished relative to that along the south shore of the channel, these data suggest that a considerable improvement in the environmental quality of the waters along the Cornwall waterfront has occurred over the past 19 years.

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Appendix 1: A List of the Major Taxonomic References.

List of Major Taxonomic References.

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Appendix 2: Species composition (No. per 516 cm²) of sampling sites
in the St. Lawrence River near Cornwall, July, 1985.

St. Lawrence Water Quality Survey

	North Shore Stations																			
	362		365		366		366A		368		368A		368B		369		369A		370	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Arthropoda:																				
AQUATIC CATERPILLARS:																				
Pyrilidae			26	8	11								1	8						
BEETLES:																				
Elmidae		1																		
Gyrinidae																				
CADDISFLIES:																				
Brachycentridae:																				
Brachycentrus																				
Hydroptilidae:																				
Hydroptila	4																			
Leptoceridae:																				
Ceraclea					1	8														
Mystacides																				
Oecetis		4		2																
Triaenodes					2								4							
Polycentropodidae:																				
Phylocentropus																				
MAYFLIES:																				
Caenidae:																				
Brachycercus																				
Caenis	4	1																		
Ephemeridae:																				
Hexagenia																				
TRUE FLIES:																				
Ceratopogonidae	4												4				1			

St. Lawrence Water Quality Survey

	North Shore Stations																			
	362		365		366		366A		368		368A		368B		369		369A		370	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
TRUE FLIES:																				
Chironomidae:																				
Chironomus	148	315	80	20	212	412	64	16			16	8	56	300	12	24	108	1	60	12
Cladopelma													9							
Cryptochironomus																		4		
Dicrotendipes																			5	
Glyptotendipes																				
Harnischia																				
Microtendipes																				
Parachironomus																				
Paralauterborniella	28	42																		
Paratanytarsus				4		4			4				9							
Paratendipes	55	63																		
Phaenopsectra	110	43	20	4	44	4	16						9	4	4	78				
Polypedilum					6	16									4	10	4			
Rheotanytarsus	28	21	4	20		24														
Stictochironomus																				
Tanytarsus																				
Tribelos					6								9						11	
Cricotopus/Orthocladius	4	3	16	32	3	8							4	4					4	
Nanocladius																				
Psectrocladius	4								4	4										
Ablabesmyia																				
Clinotanypus																				
Procladius		1			1	8									12	4	4		12	
AMPHIPODS:																				
Gammaridae:																				
Gammarus	120	44	348	180	35	276			4	6	4		252	364	312	56	4		20	236
ISOPODS:																				
Asellidae:																				
Asellus			12	8	5	12			20	24			138	568	78	40	6		12	40

St. Lawrence Water Quality Survey

North Shore Stations

[illegible]

St. Lawrence Water Quality Survey

	North Shore Stations																			
	362		365		366		366A		368		368A		368B		369		369A		370	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Annelida:																				
LEECHES:																				
Erpobdellidae				1		1							4		1	4				
Glossiphoniidae	4		1			8						8	4	6					1	16
POLYCHAETES:																	4			
Manaynunkia speciosa																				
WORMS:																				
Lumbricidae	4																			
Lumbriculidae:																				
Stylodrilus herringianus																				
Naididae:																				
Stylaria																				
Tubificidae:																				
Aulodrilus americanus																				
Ilyodrilus templetoni	4	3													4	4	48			4
Isochaetes freyi																				
Limnodrilus cervix											181	33								
L. hoffmeisteri	67	25			8	102	16		112	234	135	220	8	34	30	89	148	160	38	
L. udekemianus										13	40	18			2					
Potamothrix moldaviensis																				
Quistadrilus multisetosus															16	60	68	8	2	4
Spirosperma ferox	8	19	1		3	12											16	5		
Nematoda:																				
NEMATODES	8	2	8	8		8	16		2				16	16	4		2			
Nemertea:																				
PROBOSCIS WORMS:																				
Prostoma				4		1														
Platyhelminthes:																				
FLATWORMS	4	1	16	6	1								12		1				2	8
NUMBER OF TAXA	24	21	15	18	24	27	4	2	4	10	9	8	11	16	21	15	16	11	18	11
NUMBER OF ORGANISMS	661	611	638	401	482	1159	144	32	140	292	410	301	522	1354	645	445	542	203	219	346

St. Lawrence Water Quality Survey

North Shore Stations

[illegible]

St. Lawrence Water Quality Survey

	North Shore Stations																			
	371		371A		371B		372B		372A		372		376		373		373A		373B	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
TRUE FLIES:																				
Chironomidae:																				
Chironomus	116	43			876	657	4	3	8		30	52			8	8	4	12	448	386
Cladopelma																				
Cryptochironomus				6	21	22														
Dicrotendipes				6			4													
Glyptotendipes																				
Harnischia			3	6							9	8								
Microtendipes		5			41	22											4	23	20	
Parachironomus					10															
Paralauterborniella												8					4		20	
Paratanytarsus			3		21							16						12		
Paratendipes											18	8							20	
Phaenopsectra	4		10	6	21		4				53	33								
Polypedilum									2										12	
Rheotanytarsus									4		18	8								
Stictochironomus																				
Tanytarsus					21	22													12	41
Tribelos				12					4	2		16	2	4					20	
Cricotopus/Orthocladius	4		17	12			4						4			4			1	
Nanocladius			11				4									4				
Psectrocladius																				2
Ablabesmyia																				
Clinotanypus															4				2	11
Procladius	12	20			4	12					2	8		8	4	4			2	11
AMPHIPODS:																				
Gammaridae:																				
Gammarus	80	312	692	476	80	176	116	40	16	14	7	12	34	12	176	260	40	120	5	4
ISOPODS:																				
Asellidae:																				
Asellus	44	116	56	44	72	216	76	36		8			21	100	92	332	16		2	2

St. Lawrence Water Quality Survey

North Shore Stations

[illegible]

St. Lawrence Water Quality Survey

	North Shore Stations																			
	371		371A		371B		372B		372A		372		376		373		373A		373B	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Annelida:																				
LEECHES:																				
Erpobdellidae			4						1		1					8	4			
Glossiphoniidae					4				1	3			1		1	4	4			4
POLYCHAETES:																				
Manayunkia speciosa											2									
WORMS:																				
Lumbricidae				2							6						6	16		
Lumbriculidae:																				
Stylodrilus herringianus																				
Naididae:																				
Stylaria											4									
Tubificidae:																				
Aulodrilus americanus																				
Ilyodrilus templetoni											1		4				4		2	
Isochaetes freyi																				
Limnodrilus cervix																				
L. hoffmeisteri	35	37	36	33	4		31	8	26	7	5	11	5	55	70	148		4		
L. udekemianus															144					
Potamothrix moldaviensis																				
Quistadrilus multisetosus		4	4	8					4	3		2				8				
Spirosperma ferox				4					1	2		2					28	52	2	1
Nematoda:																				
NEMATODES				4					4		3					5	4		2	2
Nemertea:																				
PROBOSCIS WORMS:																				
Prostoma											3	6								
Platyhelminthes:																				
FLATWORMS	4	1	1	4		8			6		2		3		4		4		3	
NUMBER OF TAXA	16	16	17	22	16	13	13	6	15	14	20	26	14	10	17	18	17	19	21	23
NUMBER OF ORGANISMS	386	597	977	765	1213	1192	268	97	186	78	224	327	86	203	559	849	252	565	576	673

St. Lawrence Water Quality Survey

North Shore Stations

	375		374		374A	
	A	B	A	B	A	B
Arthropoda:						
AQUATIC CATERPILLARS:						
Pyrilidae	5	2				
BEETLES:						
Elmidae						
Gyrinidae						
CADDISFLIES:						
Brachycentridae:						
Brachycentrus					675	201
Hydroptilidae:						
Hydroptila						
Leptoceridae:						
Ceraclea						
Mystacides						
Oecetis			2			
Triaenodes						
Polycentropodidae:						
Phylocentropus			1			
MAYFLIES:						
Caenidae:						
Brachycercus						
Caenis						
Ephemeridae:						
Hexagenia						
TRUE FLIES:						
Ceratopogonidae			2		1	

St. Lawrence Water Quality Survey

North Shore Stations

	375		374		374A	
	A	B	A	B	A	B
TRUE FLIES:						
Chironomidae:						
Chironomus			1			
Cladopelma						
Cryptochironomus						
Dicrotendipes						
Glyptotendipes						
Harnischia						
Microtendipes			8			
Parachironomus						
Paralauterborniella						
Paratanytarsus						
Paratendipes						
Phaenopsectra			8			
Polypedilum						
Rheotanytarsus					1	2
Stictochironomus						
Tanytarsus			4			
Tribelos						
Cricotopus/Orthocladius						
Nanocladius						
Psectrocladius						
Ablabesmyia						
Clinotanypus						
Procladius						
AMPHIPODS:						
Gammaridae:						
Gammarus	36	8	22	8	20	17
ISOPODS:						
Asellidae:						
Asellus	104	39	45	13		

St. Lawrence Water Quality Survey

North Shore Stations

	375		374		374A	
	A	B	A	B	A	B
Mollusca:						
CLAMS:						
Sphaeriidae:						
Pisidium			19	1	19	1
Sphaerium	8	4	14	13	175	180
Unionidae:						
Elliptio						
Lampsilis						
SNAILS:						
Ancylidae:						
Ferrissia						
Bithyniidae:						
Bithynia	1	9	62	53	79	252
Hydrobiidae:						
Amnicola	12	3	45			
Probythinella						
Somatogyrus						
Lymnaeidae:						
Fossaria			3		3	
Lymnaea						
Pseudosuccinea						7
Stagnicola				1		
Physidae:						
Physa	4	1		1	1	
Planorbidae:						
Gyraulus			1		6	
Helisoma	1		1			
Promenetus						
Pleuroceridae:						
Goniobasis livescens						
Valvatidae:						
Valvata piscinalis			6	3		
V. tricarinata		1	13	5		
Viviparidae:						
Campeloma						

St. Lawrence Water Quality Survey

North Shore Stations

	375		374		374A	
	A	B	A	B	A	B
Annelida:						
LEECHES:						
Erpobdellidae						
Glossiphoniidae	3		1			
POLYCHAETES:						
Manayunkia speciosa						
WORMS:						
Lumbricidae				3		1
Lumbriculidae:						
Stylodrilus herringianus				6	85	6
Naididae:						
Stylaria						
Tubificidae:						
Aulodrilus americanus						
Ilyodrilus templetoni						
Isochaetes freyi						
Limnodrilus cervix						
L. hoffmeisteri	36	10				
L. udekemianus						
Potamothrix moldaviensis						
Quistadrilus multisetosus	4		3		1	1
Spirosperma ferox		1	36	6	42	
Nematoda:						
NEMATODES					1	
Nemertea:						
PROBOSCIS WORMS:						
Prostoma			1		4	5
Platyhelminthes:						
FLATWORMS			1		5	3
NUMBER OF TAXA	10	9	23	12	16	12
NUMBER OF ORGANISMS	209	76	299	113	1118	676

St. Lawrence Water Quality Survey

South Shore Stations

	393		392		391		390		389		388		387		386		384		383	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Arthropoda:																				
AQUATIC CATERPILLARS:																				
Pyrilidae																				
BEETLES:																				
Elmidae	3	1																		4
Gyrinidae																				
CADDISFLIES:																				
Brachycentridae:																				
Brachycentrus																			16	68
Hydroptilidae:																				
Hydroptila											1									
Leptoceridae:																				
Ceraclea					2															1
Mystacides																				
Oecetis	4		1	3					2											
Triaenodes																				
Polycentropodidae:																				
Phylocentropus	1				4		1		1				2	1	2					
MAYFLIES:																				
Caenidae:																				
Brachycercus																				
Caenis	1								2											
Ephemeridae:																				
Hexagenia													1							
TRUE FLIES:																				
Ceratopogonidae	1		2	3	1										2	1				4

St. Lawrence Water Quality Survey

South Shore Stations

[illegible]

St. Lawrence Water Quality Survey

	South Shore Stations															
	393		392		391		390		389		388		387		386	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Mollusca:																
CLAMS:																
Sphaeriidae:																
Pisidium		1	5		12	22	104	40	24	40	4	4	12		12	8
Sphaerium	1		1		4	8	4	12		4	4	1		2	8	4
Unionidae:		1							1					1		
Elliptio	3			1	1				1			1	1			1
Lampsilis	2					5		2			1	3	3		1	
SNAILS:																
Ancylidae:																
Ferrissia					6											
Bithyniidae:																
Bithynia	2			1	8	3	28	3	4	1	8	12				56
Hydrobiidae:																
Amnicola		1	6	1	14		108	64	12	10	8	4	4	4	10	60
Probythinella				2												12
Somatogyrus			1		1		4								4	
Lymnaeidae:																
Fossaria					14	1	12	24	16	35			4		84	32
Lymnaea						1	1	2								24
Pseudosuccinea		1														8
Stagnicola												1				
Physidae:																
Physa					19	1	24	4	20	53	3		12	8		8
Planorbidae:																
Gyraulus					1			12		1			20	8		
Helisoma					1				4	4	1		12	4		8
Promenetus																
Pleuroceridae:																
Goniobasis livescens					2	1					4	4				
Valvatidae:																
Valvata piscinalis		1					4									
V. tricarinata			1	2											9	12
Viviparidae:																
Campeloma								1								

St. Lawrence Water Quality Survey

	South Shore Stations																			
	393		392		391		390		389		388		387		386		384		383	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Annelida:																				
LEECHES:																				
Erpobdellidae													1							
Glossiphoniidae					1		4						4						4	
POLYCHAETES:																				
Manayunkia speciosa					1															
WORMS:																				
Lumbricidae		1				7			6	6	4	4	4	2	4	1	10	16		4
Lumbriculidae:																				
Stylodrilus herringianus		3															1			
Naididae:																				
Stylaria					12															
Tubificidae:																				
Aulodrilus americanus					2										4					
Ilyodrilus templetoni		1			6		4	4	4											
Isochaetes freyi															2	4				
Limnodrilus cervix																				
L. hoffmeisteri	11	3	2	17	4	22	45	8	40	34			8	16	2	4		2	16	8
L. udekemianus																				
Potamothrix moldaviensis	4								6											
Quistadrilus multisetosus		1					4		8	8		4								
Spirosperma ferox	19	8			75	11		8				4					112	108	4	12
Nematoda:																				
NEMATODES								4	4	5									16	
Nemertea:																				
PROBOSCIS WORMS:																				
Prostoma		1			3		4		1	8							8			
Platyhelminthes:																				
FLATWORMS							3	4	1				1							
NUMBER OF TAXA	18	19	17	15	32	20	22	23	24	30	14	12	22	16	15	6	17	18	20	21
NUMBER OF ORGANISMS	89	39	127	99	261	198	622	329	424	459	62	50	288	196	61	18	494	384	550	592

St. Lawrence Water Quality Survey

	South Shore Stations											
	382		381		380		379		378		377	
	A	B	A	B	A	B	A	B	A	B	A	B
Arthropoda:												
AQUATIC CATERPILLARS:												
Pyrilidae									1		1	
BEETLES:												
Elmidae		2	2		3	1	1					
Gyrinidae									3			1
CADDISFLIES:												
Brachycentridae:												
Brachycentrus							16	6				
Hydroptilidae:												
Hydroptila												
Leptoceridae:												
Ceraclea								3				
Mystacides												
Oecetis						1						1
Triaenodes												
Polycentropodidae:												
Phylocentropus	2				5	20						
MAYFLIES:												
Caenidae:												
Brachycercus			1						1			
Caenis						4						
Ephemeridae:												
Hexagenia	2	1			4						1	
TRUE FLIES:												
Ceratopogonidae	2	4			8		1		3	1		

St. Lawrence Water Quality Survey

	South Shore Stations											
	382		381		380		379		378		377	
	A	B	A	B	A	B	A	B	A	B	A	B
TRUE FLIES:												
Chironomidae:												
Chironomus	4	7							22	9	269	34
Cladopelma						5						
Cryptochironomus	4		12	4					10	6		
Dicrotendipes		6			21	11						
Glyptotendipes	4											
Harnischia		6										
Microtendipes					21	5	2		19	26	16	
Parachironomus											12	
Paralauterborniella										6		
Paratanytarsus									10	6		3
Paratendipes												
Phaenopsectra							2	5		6	12	3
Polypedilum		6					2	5	19			
Rheotanytarsus					21		7	15			27	
Stictochironomus			4									
Tanytarsus	8	6		2					10			
Tribelos						5				19	18	3
Cricotopus/Orthocladius			2		4	4	2	13			28	
Nanocladius												
Psectrocladius										1		
Ablabesmyia		6						4				3
Clinotanypus		2				4						
Procladius		4	1		4	8			23	10	4	3
AMPHIPODS:												
Gammaridae:												
Gammarus			1		76	36	12	9	25	30	744	18
ISOPODS:												
Asellidae:												
Asellus	2				28	8					100	6

St. Lawrence Water Quality Survey

[illegible]

St. Lawrence Water Quality Survey

	South Shore Stations											
	382		381		380		379		378		377	
	A	B	A	B	A	B	A	B	A	B	A	B
Annelida:												
LEECHES:												
Erpobdellidae											2	1
Glossiphoniidae	1		1									1
POLYCHAETES:												
Manaynunkia speciosa												
WORMS:												
Lumbricidae						2				11		
Lumbriculidae:												
Stylodrilus herringianus							1					
Naididae:												
Stylaria	2											
Tubificidae:												
Aulodrilus americanus	11	6										
Ilyodrilus templetoni												
Isochaetes freyi				7	3							
Limnodrilus cervix												
L. hoffmeisteri	17	12	3	5		28				2	135	2
L. udekemianus												
Potamothrix moldaviensis												
Quistadrilus multisetosus											4	
Spirosperma ferox					2		1	2	10	7		
Nematoda:												
NEMATODES								1				
Nemertea:												
PROBOSCIS WORMS:												
Prostoma												
Platyhelminthes:												
FLATWORMS												
NUMBER OF TAXA	14	16	12	4	15	20	18	17	20	24	19	19
NUMBER OF ORGANISMS	61	82	36	14	221	159	90	91	317	217	1581	92

Appendix 3: Field Observations of the St. Lawrence River Survey, July 1985.

St. Lawrence River Survey, July 1985

Station	Sediment Type	Depth (m)	Grab Eff. (%)	Macrophytes & Algae	Observations
362	silty-sand	3	60	macrophytes	sulphur odour
365	silty-sand	2	60	Milfoil, Elodea	marle, oil
366	silty-sand	3	80	Milfoil, Elodea	
366A	silty-sand	6	80		wood fibre, very oily samples
368	rock, gravel, ooze	1	70	Milfoil, Elodea Cladophora	oil, strong sulphur odour
368A	silty-sand	9.5	80		oil, wood fibre, marle
368B	ooze	2	100	Milfoil, Elodea	marle
369	ooze	1.5	40	Milfoil, Elodea Cladophora	
369A	silty-sand, ooze	8	80		oil
370	ooze	3.5	80	Milfoil, Elodea	oil, marle
371	silt, stone	1.5	20	Milfoil, Elodea	oil, marle
371A	silty-sand	2	40	Milfoil	marle
371B	hard silt	2	40	Elodea, Chara	
372	rock, sand	2	20	Chara Cladophora	marle
372A	silt	4	100	Chara	oil film, marle wood fibre
372B	ooze	1.5	100	Milfoil, Elodea, Chara	oil, marle, wood fibre

St. Lawrence River Survey, July 1985

Station	Sediment Type	Depth (m)	Grab Eff. (%)	Macrophytes & Algae	Observations
373	silt, clay	1.5	60	macrophytes	
373A	silt	3	80	macrophytes	oil, tar, marle wood fibre
373B	silt	3	60	macrophytes	
374	silty-sand	2	60	macrophytes	
374A	sand, gravel	14	40	macrophytes	
375	silt	1.5	100	macrophytes	marle
376	silt, ooze	2	100	Elodea	marle, organic odour
377	silt, ooze	2	80	Milfoil	
378	silt, ooze	2	60	Milfoil Cladophora	marle
379	clay	2	30	Elodea	marle
380	silty-sand	2	80	Milfoil, Elodea algae	wood chips
381	sand	2	80		fine wood chips
382	silty-sand, ooze	2	65		wood fibre, oil film
383	silty-sand	2	60	Milfoil, Elodea	marle
384	silty-sand	1.5	40	Chara	
386	silty-sand, clay	2.5	40	macrophytes	wood chips
387	ooze	2	60	Elodea	

St. Lawrence River Survey, July 1985

Station	Sediment Type	Depth (m)	Grab Eff. (%)	Macrophytes & Algae	Observations
388	silt, sand, rock	4	80	macrophytes Cladophora	marle
389	silty-sand	3	40	macrophytes	
390	silt	3.5	60	Milfoil, Elodea	
391	silty-sand, rock, ooze	3	40	macrophytes	
392	silt, ooze	4.5	100		oil
393	silty-sand	3	80		wood fibres

